MSABR 04-05

Morrison School of Agribusiness and Resource Management

Faculty Working Paper Series

A Bilateral Comparison of Fruit and Vegetable consumption: U.S. and Canada

Timothy J. Richards and Paul M. Patterson

July 2004

ARIZONA STATE UNIVERSITY

POLYTECHNIC CAMPUS

This report is also available online at http://agb.east.asu.edu/workingpapers/0405.pdf

A Bilateral Comparison of Fruit and Vegetable Consumption: U.S. and Canada

Timothy J. Richards
Paul M. Patterson[1]

December 2003
Revised July 2004

---

[1] Authors are Power Professor and Associate Professor, respectively, in the Morrison School of Agribusiness, Arizona State University, 7001 E. Williamsfield Rd., Mesa, AZ. 85212. Contact author: Patterson. Ph. 480-727-1124. FAX 480-727-1961. email: paul.patterson@asu.edu. We gratefully acknowledge the financial support of the National Research Initiative - USDA program. This paper is funded under USDA-NRI Grant No. 00-35400-9121. All opinions expressed are of the authors and not the USDA.

A Bilateral Comparison of Fruit and Vegetable Consumption: U.S. and Canada

Abstract: Many public programs promote diets rich in fruits and vegetables based on evidence on the derived health benefits. Sill, produce consumption in the U.S. lags behind other nations, even its most culturally similar neighbor–Canada. This study uses a structural latent variable model to test the role quality and health information play in explaining observed differences in produce consumption. The Alchian-Allen effect predicts that higher quality, higher absolute margin produce will be exported, suggesting that quality may be an important demand factor in importing nations such as Canada. The results show that dietary health information is significant in expanding demands. Quality also promotes fruit consumption in Canada.

Keywords: Alchian-Allen effect, fruit and vegetable trade, health information, produce quality, latent variable, MIMIC model

Introduction

Through its "5 a Day for Better Health" program, the National Cancer Institute (NCI) and the Produce for Better Health Foundation (PBH) have spent an average of $1 million per year over the last decade to promote the consumption of fruits and vegetables. The health benefits of increased consumption of these products are clearly documented in the epidemiological literature, both in terms of reduced incidence of various forms of cancer (Block, Patterson, and Subar), as well other ailments such as stroke, heart disease, and obesity. In fact, USDA estimates the annual cost to the U.S. economy of poor diets in general of $5.1 to $10.6 billion dollars in health care costs, absenteeism, and early death (Frazão). Despite efforts to promote healthy eating, the number of fruit and vegetable servings per capita per day in the United States lags that in other countries of similar level of economic development (Waterfield, 1997; Johnson; Offner). Of particular concern is the stark difference in consumption between the United States and its largest, and most culturally similar neighbor – Canada. Whereas average consumption of fresh fruits and vegetables in the United States is approximately 3.6 servings per capita per day, Canadians consume an average of six to seven servings per day. However, there is some debate over these differences due to the use of alternative methodologies in determining these rates (Burfield). If accepted, it is curious that this difference persists in spite of the fact that Canada's climate does not allow for widespread production of produce year-round, as in the United States, with the notable exception of greenhouse tomatoes. This necessitates the importation of a large proportion of Canada's produce needs, largely from the United States. In fact, Canada imports approximately 86 percent of the fruit and 39 percent of the vegetables it consumes (Statistics

Canada, 2001) with the United States accounting for approximately 53 and 80 percent of these imports, respectively (Industry Canada).

Explanations for the difference in consumption range from differences in ethnic composition, income, relative prices, the propensity to purchase and consume food away from the home, knowledge regarding the link between diet and health, and the quality of available produce (Waterfield, 1997; Johnson; Offner; Burfield). Of these factors, ethnicity, income, prices and the proportion of food consumed away from the home are relatively easy to account for econometrically. However, knowledge and quality are less straightforward to measure. Nonetheless, it is necessary to do so because quality and knowledge, or more specifically differences in quality and knowledge, are likely to be important determinants of consumption patterns in the U.S. and Canada.

Differences in quality may be explained by the Alchian and Allen theorem, where it is argued that when goods of different quality incur the same per unit transportation costs, high quality, higher priced goods become relatively less expensive in the destination market, than in the production region. Therefore, there is greater demand for the higher quality good in the import region, as consumers substitute higher quality goods for lower quality goods (Alchian and Allen). This leads to the commonly observed practice in the produce industry of "shipping the good apples out" (Borcherding and Silberberg). As a result, Canadians generally see higher quality produce than consumers nearer the production regions in United States. This outcome was discussed in a Washington State consumer's letter to the *Seattle Times* (October 19, 1975):

Why are Washington apples in local markets so small and old-looking? ... Recently, some apple-picking friends brought some apples they had just picked, and they were at least *four times the size of those available for sale here. Where do these big Delicious apples go? Are they shipped to Europe, to the East or can they be bought here in Seattle?* (see Borcherding and Silberberg).

For this consumer, size and freshness are important attributes determining the product's quality. As discussed further below, quality is a multidimensional construct incorporating many attributes that induce consumers to pay more. Furthermore, quality plays other well known roles in produce markets. Marketing studies have shown that produce quality plays an important role in the retail grocery stores that consumers choose for their food shopping (Arnold, Oum and Tigert; Walters and McKenzie). Consumer surveys have also shown that quality is an factor in influencing produce consumption (Scott).

Differences in dietary knowledge may also exist in the United States and Canada. Like the United States, Canada also has a public-private social marketing campaign to promote the consumption of fruits and vegetables. However, the Canadians have been promoting this message for at least two decades longer than the United States and it is reported to air more frequently on television in Canada (Burfield). The promoted goal in Canada has also surpassed the U.S. goal of "five a day," as Canadian health authorities are now encouraging consumers to "reach for ten" servings of fruits and vegetables. Given these differences in message and the reported differences in the achievement of their proclaimed goals, the availability of information or knowledge on the importance of fruit and vegetables in a healthy diet is also a likely important factor explaining differences in produce consumption.

Accounting for the effect of information in econometric models of demand, however, remains a contentious issue. Many studies include various measures of advertising exposure or indices of consumer information in the attempt to estimate the effect of information on demand (Ippolito ; Alston *et al.*; Richards; Kinnucan, *et al.;* Teisl and Roe; Brown and Schrader). While the inclusion of information in this way is often possible in time-series studies on the assumption that all individuals or households receive the same level of exposure to the advertisement or information source through alternative media outlets and that this exposure translates into consumer awareness or concern. Alternatively, information-induced changes in demand may be captured by trend variables or dummy variables. Yet, this raises concerns over whether these variables, which agglomerate all time varying variables, truly identify the impact of the specific information of concern. Alternatively, appropriately designed surveys may estimate demand as a function of individual awareness or knowledge (Teisl and Roe). Studies using the USDA's Continuing Survey of Food Intake by Individual (CFSII) and its companion survey the Dietary Knowledge Health Survey (DKHS; U.S. Department of Agriculture) or similar data (Jensen and Kesavan; Jensen, Kesavan, and Johnson; Gould and Lin; Kim et al.) are relatively rich in being able to measure individual households' level of information regarding both the foods they consume and their links to a healthy diet. However, there are three problems with using these data. First, such surveys typically do not contain product prices, so one potentially important determinant of variation in demand among households is ignored. Second, there are no comparable data for Canadian households, so a comparison of estimates from such disparate data sets would be tenuous at best. Third, even responses to direct questions regarding dietary knowledge remain only indirect measures of actual knowledge as knowledge is inherently unobservable so must be specified as a latent variable (Variyam, *et al.*).

Accounting for the impact of quality on consumer demand has also been a difficult matter in empirical studies. While many studies adopt Cox and Wohlgenant's application of Goldman and Grossman's hedonic approach to account for differences in product quality, the assumption that households of similar demographic or socioeconomic attributes purchase similar product may be of some question. This assumption is often useful, but by no means an exact method of accounting for variation in quality, nor for explaining how quality influences quantity demand. Alternatively, Davis and Hewitt develop an approach based on the economic theory of index numbers to impute variations in quality of imported goods based on differences between their import unit values and market prices. However, such data are not readily available for domestically produced and consumed goods so quality, like information, is most appropriately specified as a latent construct.

Despite the importance attached to fresh fruit and vegetable consumption by public health authorities, neither the role of quality or dietary knowledge have been rigorously documented or verified. Therefore, the objectives of this paper are to: (1) determine whether the accepted difference in U.S. and Canadian consumption of fresh fruits and vegetables is real or an artifact of different measurement systems, and (2) explain the gap as a result of prices, incomes, tastes and preferences, dietary health knowledge, or average produce quality. To achieve these objectives, we estimate the impact of quality and dietary health knowledge on fresh produce demand in each country using retail scanner data within a structural latent variable framework.

Empirical Model of Fresh Produce Demand

Food quality is determined by a combination of attributes, such as taste, aroma, texture, color or size, and consistency in these and other attributes on each consumption occasion. Although packaged food products are widely regarded as experience goods (Nelson) with regard to their quality attributes, they are distinctly different from produce. Today's food manufacturers can, through careful input selection and processing adjustments, deliver products that are nearly uniform over time. Furthermore, an implicit warranty of this quality is often offered through a packaged good's brand name. However, these opportunities elude retail marketers of fresh produce, whose quality attributes are inherently variable, not fully appreciated by the consumer until they are consumed on each occasion, and generally not identifiable through a brand name. As such, produce is more of an experience good than processed foods on the continuum that classifies goods as experience or search goods. Given the variability in product attributes and experiential nature of the product, produce quality remains an unobservable variable. Similarly, the dietary knowledge that consumers hold on the benefits of produce consumption is unobservable. Although U.S. consumers are reminded to eat "five a day," the benefits may not be fully understood. The benefits of produce consumption are complex and multifaceted (the prevention of various forms of cancer, consumption of essential micro-nutrients, or healthy weight maintenance to name a few) and cannot be reduced to a simple claim, as on many packaged goods, which may be substantiated by the information in the nutrition. Such labeling is generally not available for produce. Thus, measures of information content or exposure are not available, much less measures of consumer knowledge acquired through processing this information. Therefore, both quality and knowledge must be treated as latent variables, requiring appropriate methods to capture their impact on demand.

Consequently, this study uses a two-stage approach to determine the impact of both unobservable factors on produce demand in Canada and the U.S.. In the first stage, latent variable models of quality and dietary knowledge are estimated for both the U.S. and Canada. Fitted values for quality and knowledge derived from the first-stage models are then used in a set of second-stage fresh produce demand models to test the impact of quality and information on fruit and vegetable demand in each country. The specific form of the first-stage latent variable model is based on the structural latent variable approach of Joreskog and Goldberger (1971), who derive a method of identifying and estimating the impact of unobservable variables on observable quantities. Within the general class of structural latent variable models, this study uses a multiple indicator, multiple cause (MIMIC) approach. Gao and Shonkwiler use a similar method to estimate the impact of changes in tastes and preferences on the demand for various types of meat in the U.S., while Patterson and Richards and Richards, Gao and Patterson apply a MIMIC technique to estimate the effect of advertising on the demand for fresh fruit. Variyam, *et al.* use a similar, yet somewhat simplified, factor analysis approach in estimating the latent effect of nutritional information on an index of dietary health.

A MIMIC model is appropriate, because latent variables are typically modeled with proxies. Standard proxy variable models, however, are generally unacceptable for several reasons. First, proxy variables are erroneous measures of the true latent variables upon which demand is thought to depend, introducing potentially significant measurement error and, hence, inconsistency. Second, latent variables are likely to be endogenous. Thus, ordinary least squares, or any other limited-information approach, introduces potentially significant simultaneous equations bias. Third, introducing a single proxy variable may provide misleading results simply because there are many other possible proxies for any latent variable, each leading to a different estimate of the true effect. Consequently, measuring product quality and information, as well as their effect on consumption, requires an approach that not only explicitly recognizes the inherent latency of each, but also the many possible ways of measuring them.

A MIMIC model relies on covariance relationships between observable endogenous "indicators" of latent variables and exogenous observable "causes" to identify latent variable values that are otherwise unobservable. Formally, MIMIC models consist of two sets of equations: (1) measurement (or indicator) equations that describe the relationships between indicator variables and latent constructs, and (2) causal or structural equations that show how these latent variables are determined by observable, exogenous economic variables. While measurement equations are used to scale and identify the latent constructs, causal equations provide the parametric estimates that are of key interest to researchers. Formally, and in general notation, structural equations specify relationships between the set of latent variables (η), their causes ($\boldsymbol{z}$), and a random error term (ζ):

$$\boldsymbol{\eta} = \boldsymbol{\Phi\eta} + \boldsymbol{\Gamma z} + \boldsymbol{\zeta}, \qquad \textbf{(1)}$$

where Φ and Γ are parameter vectors showing the marginal effects of the latent variables on each other and of cause variables on latent variables, respectively. Measurement equations, on the other hand, show how each indicator variable ($\boldsymbol{y}$) is related to the latent variables, a vector of exogenous factors ($\boldsymbol{x}$), and a vector of random measurement-errors (Joreskog and Goldberger; Bollen; and Anderson):

$$\boldsymbol{y} = \Lambda_y \boldsymbol{\eta} + \boldsymbol{\beta x} + \epsilon. \tag{2}$$

In this set of equations, the components of Λ_y are also known as factor loading coefficients. Further, the error terms of (1) and (2) are uncorrelated with each other, have zero means, and have covariance matrices given by Ψ and Θ, respectively. These covariance matrices are central to the estimation method. Whereas ordinary least squares regression finds parameter estimates by minimizing the sum of squared deviations between the fitted and observed values of $\boldsymbol{y}$, the fact that some of the dependent variables in a MIMIC model are unobserved makes this impossible (Gao and Shonkwiler; Bollen). Therefore, estimates of the model parameters are found instead by minimizing the difference between the sample covariance matrix of observed variables (**S**) and a fitted covariance matrix ($\Sigma(\theta)$) for a parameter vector, θ (see Bollen, Browne, and Ivaldi, *et al.*).

In comparing the demand for fresh produce between the U.S. and Canada, there are primarily two latent variables: "quality" and "information." Each latent variable requires at least two indicator equations in order to both scale and identify its value. The first set of indicator equations serve to identify quality and, therefore, consist of hedonic pricing models for fruits and vegetables in each country. Based on the logic of Goldman and Grossman and Cox and Wohlgenant, households of different socioeconomic makeup are assumed to demand variants of the same type of food that differ in terms of their inherent quality. For example, both lower

$$\ln y_i^K = \sum_m \alpha_{im} x_{im}^K + \Lambda_{iK} K + \epsilon_i, \tag{3}$$

income and higher income households may consume beef, but higher income households are more likely to purchase high quality steaks, while lower income households will buy ground beef. Therefore, regional variations in household characteristics may explain regional differences in price, which may in turn reflect underlying differences in quality. Specifically, the log of price (y_i^K) is a function of a vector of household attributes (x_{im}^K) that includes household income, household income squared, and family size and a latent quality (K) variable:

for each type of produce, i. In this model, Λ_K for fruit (vegetables) is normalized to 1.0 for the U.S. (Canadian) model in order to scale the latent variable value. Information indicators, on the other hand, should reflect the extent of consumer knowledge of the health benefits of a diet rich in fruits and vegetables. Revealed consumption behavior is a logical choice as consumers who are well informed are more likely to choose to buy fruits and vegetables if they are concerned about the quality of their diet. Similarly, more educated consumers are assumed to be better able to access health-related dietary information and to be able to process available information more effectively. Therefore, the set of indicators includes total produce consumption and educational expenditures. Additional exogenous variables ($\boldsymbol{x}$) entering these indicator equations include demographic variables and an index measure of available dietary information on fruit and vegetable consumption constructed using the *Reader's Guide to Periodicals*. This index is similar to the one used by Brown and Schrader in their analysis of cholesterol awareness. In general notation, these information measurement (indicator) equations are written as:

$$y_k^I = \sum_j \beta_{jk} x_{jk}^I + \Lambda_{kI} I + \epsilon_k, \tag{4}$$

where *I* is the latent information construct and *k* indexes either education expenditure or total produce consumption. Identifying each latent variable with the measurement model, however, does not necessarily explain variation in quality and information over panel observations.

Structural, or causal, equations serve this purpose. The structural equation for information includes other exogenous, causal factors that may contribute to a consumer's access to and use of nutritional information. Previous research on the role of dietary knowledge on food choices suggests that race is an important determinant of the extent to which available information is taken into account (Gould and Lin) in making food choices. Further, consumers who tend to eat many meals away from the home necessarily lack the same type of detailed information regarding the nutritional content of their meals. Therefore, causal information variables include the size of the minority population in a region, expenditures on food away from home, and participation by women in the workforce (z_k^I). Again in general notation, the structural equation is written as:

$$I = \sum_k \gamma_k z_k^I + \xi_1, \tag{5}$$

where *I* varies over all panel observations. With respect to quality, the causal variables reflect other demographic factors that are more likely to determine quality choices directly, and not through prices as in the measurement model. Specifically, variation in the demand for quality among households depends upon the average number of children per household, the proportion of women in the workforce, and the amount of expenditure on food away from home. Households with children are likely to choose higher quality foods out of concern over their children's health outcomes, so this effect is expected to be positive. Women's participation in the workforce, however, is likely to be associated with lower quality food purchases as the demand for convenience takes precedence over nutritional goals. For many people, restaurant meals represent a means by which they are able to diversify their personal menus so new dietary trends often begin in restaurants and find their way into home-prepared meals. Therefore, expenditures on food away from home are expected to have a positive effect on the demand for quality. Combining each of these causal factors, the structural equation for quality becomes:

$$K = \sum_{l} \gamma_l z_l^K + \xi_2, \tag{6}$$

where quality (K) again varies over all panel observations. Parameterizing each latent variable in this way is necessary because it allows for the calculation of fitted information and quality indices.

In the second stage, these latent indices are used in a model of fresh produce demand. Because there is no comparable data for other food categories, the demand model is specified as a set of quantity-dependent, Cobb-Douglas demand equations. Specifically, the demand equations for produce type i are, therefore, written as:

$$\ln q_{it} = \beta_0 + \beta_1 \ln p_{it}^r + \sum_j \beta_{2j} \ln P_{jt}^r + \beta_3 \ln X_t + \beta_4 I_t + \beta_5 K_t + \epsilon_{it}, \tag{7}$$

for each country where q_{it} is the total quantity of fruit or vegetables purchased per capita, p_{it}^r is the price of fruits or vegetables measured as a weighted average of all the products purchased, P_{jt}^r are prices of substitute and complementary products in demand, X_t measures weekly expenditures on produce, and I_t and K_t are the latent information and quality variables. Given that the objective of this analysis is to explain observed differences in the total demand for fruits and vegetables, data on individual products are aggregated into two broad categories. These aggregates are defined for a number of regions within both countries and are recorded on a weekly basis, as explained in more detail in the next section.

Data Description and Estimation Methods

Clearly, much of the controversy over apparent differences in U.S. and Canadian produce consumption lies in defining comparable data sources. Because official government data sources differ widely in their definition of what constitutes fresh fruits and vegetables, private data sources are more likely to be able to provide similar data for both countries. Consequently, this study uses relatively high frequency, retail-scanner data gathered from same-format grocery outlets. In order to incorporate regional socioeconomic data, the scanner data are aggregated from a store-level to a regional-level on a weekly basis for the year 2000. For the U.S. model, the data are provided by FreshLook Marketing of Chicago, Illinois. Sales by grocery retailers are available on 35 fresh fruit and 51 fresh vegetable products for eight regions in the United States (Great Lakes, Midsouth, Northeast, Plains, South Central, Southeast, West, and California) and account for approximately 90 percent of the retail sale of produce in these regions. Prices for other food products were obtained from the Bureau of Labor Statistics. Regional sociodemographic variables are developed using state-level data available from the 2000 U.S. census. Data on retail grocery and restaurant sales were used to develop a weekly measure of away from home food consumption expenditures. Table 1 provides summary statistics for each variable in the U.S. model.

The Canadian retail data, supplied by A.C. Nielsen Canada, provides sales on 71 fruit products and 107 vegetable products from six regions defined as individual provinces or combinations of provinces–Alberta, British Columbia, Ontario, Quebec, the Maritime provinces (Newfoundland, Prince Edward Island, Nova Scotia, and New Brunswick), and a combination of Manitoba and Saskatchewan. Like the U.S. data vendor, A.C. Nielsen Canada also achieves approximately 90 percent account coverage and develops weekly projections for each region. Only sales data on fruits and vegetables are available in this sample, so price indices for substitute food products were developed from Statistics Canada's *CANSIM* 2 data base. These prices are available on a monthly basis for each region. A cubic spline extrapolation technique was used to develop weekly measures of these variables for use with the scanner data. The *CANSIM* database also provides regional socioeconomic measures used in the measurement and structural equations for quality and information. These data, which measure regional characteristics, like population, women's participation in the workforce, the presence in children of children in the household, are only available on an annual basis. The Canada data are summarized in table 2.

[tables 1 and 2 in here]

Each demand model is estimated using a two-stage procedure. In the first stage, the MIMIC model is estimated and fitted index values for both the quality and information latent variables are calculated. Each of these indices is then substituted into the second-stage demand models. While the second-stage model is estimated using least-squares, the MIMIC model is estimated with maximum likelihood methods using the Amos software package (SmallWaters

Corporation). In the following section, we first compare fruit and vegetable consumption levels before describing and interpreting the results obtained for each stage of the analysis.

Results and Discussion

Based on the official government data for each country, Canadians consume 414 pounds of fruits and vegetables per capita on average over the sample period, while Americans consume only 274 pounds (StatsCan, USDA). However, this comparison is misleading due to the differences in how the data are recorded in the two countries. For example, Canadian officials record consumption of frozen potatoes (French fries) as a fresh vegetables. Such discrepancies are not encountered, however, when comparing produce sales in each country using the panel data. Indeed, these data allow us to literally compare apples to apples and oranges to oranges, thereby providing several noteworthy differences. For example, the apparent annual per capita consumption of bananas in the U.S. and Canada are 13.6 and 27.6 pounds, respectively. A similar disparity in consumption levels is observed between U.S. and Canadian apple consumption (7.1 pounds versus 15.1 pounds), and oranges (5.8 pounds versus 13.0 pounds). Explaining these differences in consumption, however, requires more formal statistical analysis to control for other intervening factors.

Recall that, for each country, the quality measurement model consists of hedonic model specifications wherein variations in fruit and vegetables prices, used as indicators of quality, are explained by household income and family size (table 3). The latent quality variable coefficient is normalized to 1.0 in the fruit (vegetable) price equation for the U.S. (Canada), but the factor loading coefficient is positive and significant in the other price equation, suggesting that the hedonic models serve as a good indicator for quality. The results for the structural equation show that quality is in turn positively related to the presence of children in the household, but negatively related to increased workforce participation by women in the U.S. Both of these results are as expected. In Canada, increases in away from home consumption also resulted in higher levels of quality, as hypothesized. Two indicators of information or knowledge of the dietary health benefits of produce consumption are used in the U.S. and Canadian models. Because aggregate education spending is an endogenous pubic policy choice, per pupil expenditure on schools is used as a knowledge indicator. Based on the results in table 3, educational expenditures decline in the number of college graduates in a region, but rise with income in the U.S. The latent information variable coefficient is normalized to 1.0 in this equation for the U.S., but is unrestricted in the other indicator equation, where the total pounds of produce sold per capita serves as an indicator of dietary health information. As expected, information also has a positive and significant impact on produce consumption in the U.S. However, the structural equation for information shows that dietary health information is negatively related to the proportion of minorities in the population. This emphasizes the continued need for dietary health information campaigns targeted at these population segments (table 3). In general, these results show that the MIMIC models used to identify the latent quality and information constructs are very similar for the U.S. and Canada in a qualitative sense. However, the relative magnitude of the fitted values for these latent variable indices are quite different.

The mean values of these indices are given at the bottom of table 3. Although each index is scaled differently in each country, the relative values of the indices provides some evidence on the importance of each in potentially influencing demand. In the U.S. the information index is nearly three times the magnitude of the quality index, while the quality index is more than twice the magnitude of the information index in Canada. This indicates that the quality embodied in the produce in Canada, when scaled by the available information, is higher than in the U.S. Indeed, this is verified using a test on the differences in the means of the ratios of quality to information. This provides some primary evidence that quality is higher in Canada and adds considerable support to the Alchian-Allen hypothesis. It remains, however, to determine the role these variables play in produce demand in each country.

[table 3 in here]

The fit of all four demand models is relatively good, as indicated by the high coefficients of determination, which range from 0.80 to 0.89. Furthermore, the signs of the estimated parameters are consistent with prior expectations. Each model has significant, negative own-price coefficients and positive, significant expenditure coefficients, each of which are interpreted as elasticities in this double-log specification. The pattern of these elasticities is quite similar across countries as well. With price and expenditure elasticities similar across each country, differences in consumption may be related to the influence of quality and information. Since the demand variables were estimated using fitted quality and information variables, these variables are also specified in log form. However, the results in table 4 show that quality does not have a significant effect on fresh fruit or vegetable demand in the U.S. Quality, though, has a significant and strong effect on fruit demand in Canada. This provides strong support for the effect Alchian-Allen theorem on quality and, hence, differences in consumption. This result is also consistent with prior findings obtained by estimating a similar MIMIC model using aggregate, time series, per capita fruit and vegetable consumption data so is clearly robust to both model specification and data definition.

[table 4 in here]

Contrary to the quality results, information has a significant, positive effect on vegetable demand in the United States. Therefore, while changes in prices or incomes in the U.S. have only a modest impact on vegetable consumption, information such as that provided by the 5-A-Day campaign may play a significant role in supporting vegetable demand. Information also plays a significant role in promoting fruit consumption in Canada. However, vegetable demand is adversely affected by both quality and information in Canada. Given the way quality was measured, the negative effect on vegetable demand may partly reflect a confounding price effect as the measurement model may not have created an index that is entirely orthogonal to the price series. It may also be the case that the quality of U.S. and Canadian-consumed vegetables simply does not differ as much as it does with fruit. Many vegetables are now grown in greenhouses in Canada, so there is little need to import higher value products, while lower value products such as potatoes or carrots are inherently less variable in terms of taste and consistency. In contrast, despite a significant domestic apple supply most Canadian fruit is imported. Nonetheless, taken together these results do provide a very clear indication of the true cause of observed differences in fruit consumption between the U.S. and Canada.

Given that this study finds a significant impact of quality on fruit demand in Canada, and fruit is largely imported from the U.S. and elsewhere, this study finds considerable support for the Alchian-Allen effect as an explanation for observed differences in produce consumption between the U.S. and Canada. Indeed, if fresh fruit is costly to import, with lengthy inspection, long transport routes and expensive refrigeration technology, the best quality fruit is likely to be sent to export markets, since these costs are invariant to quality. Our findings in this regard are not only consistent with the Alchian-Allen hypothesis, but also with the conventional wisdom in industry. Consequently, the "produce consumption gap" referred to in the introduction should be of little surprise. Information is also important in explaining Canadian fruit demand, but plays a smaller role than quality. Given the relative intensity of the "Reach for It" campaign in Canada, it may be the case that although the information elasticity value is lower than the quality elasticity, the underlying information variable is rising at a faster rate. This would go a long way toward explaining observed consumption trends in Canada relative to the U.S., but requires corroboration to be completely convincing.

Conclusions and Implications

This research seeks to explain the source of the observed difference in fruit and vegetable consumption between the U.S. and Canada. Despite their demographic and socioeconomic similarity, Canadians consume far more servings of fruits and vegetables each day compared to their U.S. counterparts – an observation that, although challenged by some, is confirmed using retail-level scanner data on produce sales in each country. Because prices tend to be higher in Canada, and incomes lower, we hypothesize that this difference in consumption levels is due in part to the superior quality of imported Canadian produce. Canadian produce is generally believed to be of higher quality due to the fact consumers in import regions tend to substitute towards higher quality products, once transportation charges and other shipping costs, which are invariant to quality, are applied, as predicted by the Alchian-Allen effect. Econometric tests of the Alchian-Allen effect, however, have been rare due to the fact that measures of quality are not generally available.

Consequently, we test the Alchian-Allen hypothesis by estimating structural latent variable (MIMIC) models of fresh produce quality, information and consumption. In this way, we account for as many other explanations for the observed difference in U.S. and Canadian produce consumption as possible and then test for the independent effect of quality. With a MIMIC approach, implied latent-variable values are estimated and then used as explanatory variables in models of produce demand in order to test the impact of quality and information on fruit and vegetable consumption. In this way, we account for the potentially confounding effects of price and expenditure differences between the two countries while estimating the independent effect of quality and information. Estimates of the entire two-stage MIMIC - demand model are obtained using a retail scanner data set made up of weekly observations during a one-year period across a number of regions in each country.

The empirical results show that information explains very little of the trend in U.S. fruit consumption, and is only weakly responsible for changes in the demand for vegetables. In Canada, however, information has had a strong positive effect on fruit consumption. Quality appears to have had no effect on the demand for either fruits or vegetables in the U.S., but a significant impact on the demand for fruits in Canada. Consequently, much of the gap between Canadian and U.S. fruit consumption appears to derive from the higher average quality of fruit imported by, and consumed in, Canada. Thus, the Alchian-Allen effect is partly responsible for some of the observed difference in produce consumption rates between the two countries.

The implications of this research for academic, public policy and commercial interests are many. Given their mandate to promote fruit and vegetable consumption, public health officials at the NCI and allied state health agencies clearly have an interest in the information we provide on the factors influencing fruit and vegetable consumption. Understanding the role of information in increasing fruit and vegetable consumption can help public health officials design more effective public awareness programs and, potentially, secure higher funding for these programs in the future. Growers and shippers in the U.S. need marketing research such as this in order to better understand the dynamics underlying not only export markets, but the domestic market as well. Because the U.S. and Canadian markets are relatively homogeneous in terms of their socioeconomic makeup, it is likely the case that quality can be made to be as important in the U.S. as it is in Canada if consumers are given the choice of high quality produce over a period of time. The importance of this issue in the produce industry press is not surprising, given that moving from the current estimated consumption level of about 3.5 servings per day to the 5 a Day goal would result in a 30 percent increase in shipments for growers.

References

Alchian, A. and R. Allen. *Exchange and Production: Competition, Coordination, and Control*. 3rd ed. Wadworth Publishing Co., Belmont, California, 1983.

Alston, J.M., J.A. Chalfant, J.E. Christian, E. Meng, N.E. Piggott. *The California Table Grape Commission's Promotion Program: An Evaluation*, Research Report, Department of Agricultural Economics, University of California, Davis, July 1996.

Anderson, T. W. "Linear Latent Variable Models and Covariance Structures." *Journal of Econometrics* 41(1989): 91-119.

Arnold, S., T. Oum, and D. Tigert. "Determinant Attributes in Retail Patronage: Seasonal, Temporal, Regional and International Comparisons." *Journal of Marketing Research* 20(1983): 149-157.

Block, G., B. Patterson, and A. Subar. "Fruit, Vegetables, and Cancer Prevention: A Review of the Epidemiological Evidence." *Nutrition and Cancer* 18(1992): 1-29.

Bollen, K. *Structural Equations with Latent Variables.* New York: John Wiley and Sons. 1989.

Borcherding, T.E. and E. Silberberg. "Shipping the Good Apples Out: The Alchian and Allen Theorem Reconsidered." *Journal of Political Economy*, 86(1978):131-138.

Brown, D. J. and L. F. Schrader. "Cholesterol Information and Shell Egg Consumption." *American Journal of Agricultural Economics* 72(1990): 548-555.

Browne, M. W. "Asymptotically Distribution-Free Methods for the Analysis of Covariance Structure." *British Journal of Mathematical and Statistical Psychology* 37(1984): 62-83.

Burfield, T. "U.S. in Catch-up Mode: Canadians Consume More Produce than Americans." *Produce Marketing*, January 2003.

Cox, T. L. and M. K. Wohlgenant. "Prices and Quality Effects in Cross-Sectional Demand Analysis." *American Journal of Agricultural Economics* 68(1986):908-919.

Davis, G. C. and W. J. Hewitt. "Measuring the Quality of Imported Tobacco." *Journal of Agricultural and Applied Economics*, 28(1996):148-158.

Frazão, E. "High Costs of Poor Eating Patterns in the United States," in *America's Eating Habits: Changes and Consequences,* E. Frazão, ed., Food and Rural Economics Division, Economic Research Service, U.S. Department of Agriculture. Agriculture Information Bulletin No. 750 (AIB-750), 1999.

Gao, X. M. and J. S. Shonkwiler. "Characterizing Taste Change in a Model of U.S. Meat Demand: Correcting for Spurious Regression and Measurement Errors." *Review of Agricultural Economics* 15(1993): 313-324.

Gertler, P. J. "A Latent-Variable Model of Quality Determination." *Journal of Business and Economic Statistics* 6(1988): 97-104.

Goldman, F. and M. Grossman. "The Demand for Pediatric Care: An Hedonic Approach." *Journal of Political Economy*; 86(1978):259-280.

Gould, B. W. and H. C. Lin. "Nutrition Information and Household Dietary Fat Intake." *Journal of Agricultural and Resource Economics* 19(1994): 349-365.

Industry Canada. *Stategis - Trade Data Online*. http://strategis.ic.gc.ca/sc_mrkti/tdst/engdoc/tr_homep.html.

Ippolito, P.M. "Information, Advertising, and Health Choices: A Study of the Cereal Market." *Rand Journal of Economics*, 21(1990):459-480.

Ippolito, P. M. and A. D. Mathios. "Information and Advertising: The Case of Fat Consumption in the United States." *American Economic Review*, 85(1995):91-95.

Ivaldi, M., S. Monier-Dilhan, and M. Simioni. "Stochastic Production Frontiers and Panel Data: A Latent Variable Framework." *European Journal of Operational Research* 80(1995): 534-547.

Jensen, H. H., and T. Kesavan. "Sources of Information, Consumer Attitudes on Nutrition, and Consumption of Dairy Products." *Journal of Consumer Affairs* 27(1993): 357-376.

Jensen, H. H., T. Kesavan, and S. R. Johnson. "Measuring the Impact of Health Awareness on Food Demand." *Review of Agricultural Economics* 14(1992): 299-312.

Johnson, G. "Numbers Continue to Rise." *The Packer*, December 29, 1997.

Joreskog, K. G. and A. S. Goldberger. "Estimation of a Model with Multiple Indicators and Multiple Causes of a Single Latent Variable." *Journal of the American Statistical Association* 75(1975): 631-639.

Kim, S.Y., R. Nayga, O. Capps, Jr. "The Effect of Food Label Use on Nutrient Intakes: An Endogenous Switching Regression Analysis." *Journal of Agriculture and Resource Economics* 25(2000): 215-241.

Kinnucan, H.W., H. Xiao, C.J. Hsia, and J.D. Jackson. "Effects of Health Information and Generic Advertising on U.S. Meat Demand." *American Journal of Agricultural Economics*, 79(1997): 13-23.

Nelson, P. "Information and Consumer Behavior." *Journal of Political Economy*, 78(1970):311-329.

Offner, J. "Canadians Eat 4 Servings a Day." *The Packer*, p. C6, July 19, 1999.

Park, J. L. and O. Capps, Jr. "Demand for Prepared Meals by U.S. Households." *American Journal of Agricultural Economics* 79(1997): 814-824.

Patterson, P. M. and T. J. Richards. "Newspaper Advertisement Characteristics and Apple Variety Attraction: A MIMIC Model Approach." *Agribusiness: An International Journal*, 1999.

Putnam, J. J. and J. E. Allshouse. *Food Consumption, Prices, and Expenditures, 1970-97*, Food and Rural Economics Division, Economic Research Service, U.S. Department of Agriculture. Statistical Bulletin No. 965, 1999.

Richards, T. J. "Dynamic Model of Fresh Fruit Promotion: A Household Production Approach." *American Journal of Agricultural Economics*, 81(1999):195-211.

Richards, T. J., and X. M. Gao, and P. M. Patterson. "Advertising and Retail Promotion of Washington Apples: A Structural Latent Variable Approach to Promotion Evaluation." *Journal of Agricultural and Applied Economics*, 31(1999):15-28.

Scott, Debra. The Research Department. Seattle, WA. Personal communication, September, 1998.

SmallWaters Corporation. *Amos Users' Guide: Version 3.6*. Chicago, IL, 1997.

Statistics Canada. *Food Consumption in Canada: Part II, 2001*. Agriculture Division, Livestock and Animal Products Sections, Catalog No. 32-230-XIB, 2001.

Statistics Canada. *CANSIM II.* http://cansim2.statcan.ca/cgi-win/cnsmcgi.exe? CANSIMFile= CII/CII_1_E.HTM&RootDir=CII/) Ottawa, Canada. May 2002.

Teisl, M.F. and B. Roe. "The Economics of Labeling: An Overview of Issues for Health and Environmental Disclosure." *Agricultural and Resource Economics Review*, __(1998):140-150.

United States Department of Commerce. Bureau of Economics Analysis. http://www.bea.doc.gov/ bea/dn/nipaweb/index.asp). Washington, D.C. May 2002.

United States Department of Labor. Bureau of Labor Statistics. http://data.bls.gov /cgi-bin/dsrv?cu). Washington, D.C. May 2002.

United States Department of Agriculture. Agricultural Research Service. "Continuing Survey of Food Intake by Individuals 1994-96 and 1998." CD-ROM. 2000.

Variyam, J. N., J. Blaylock, D. Smallwood, and P. P. Basiotis. "USDA's Healthy Eating Index and Nutrition Information." Food and Rural Economics Division, ERS-USDA. Tech. Bull. No. 1866.

Walters, R. G. and S. B. McKenzie. "A Structural Equation Analysis of the Impact of Price Promotions on Store Performance." *Journal of Marketing Research* 25(1988): 51-63.

Waterfield, L. "Canada a Hungry Market." *The Packer*, p. A1-A2, November 17, 1997.

Table 1. U.S. Panel Data Summary.

Variable	N	Mean	Std. Dev.	Min.	Max.
Fresh Fruit Qty (lbs. per capita, weekly)	416	0.987	0.213	0.595	1.923
Fresh Veg. Qty (lbs. per capita, weekly)	416	0.969	0.181	0.599	1.580
Fresh Fruit Price ($/lb)	416	0.931	0.115	0.616	1.324
Fresh Vegetable Price ($/lb)	416	0.886	0.080	0.685	1.524
Meat Price (index)	416	154.705	2.291	150.062	160.122
Dairy Price (index)	416	160.753	0.968	158.793	162.487
Grain Price (index)	416	188.479	2.031	185.530	196.453
Canned Fruit Price (index)	416	106.900	1.420	104.726	110.967
Canned Vegetables Price (index)	416	106.932	1.879	102.797	114.610
Produce Expend. (cent per capita, wkly)	416	0.103	0.020	0.062	0.180
Household Income ($ 1000, annual)	416	42.231	3.254	37.506	47.493
Family Size (no.)	416	3.141	0.125	3.016	3.430
Educ. Expend. ($ per pupil, annual)	416	4.139	0.737	3.524	5.938
College Graduates (proportion)	416	0.242	0.021	0.217	0.275
Households with Children (proportion)	416	0.330	0.017	0.311	0.358
Women in Workforce (proportion)	416	0.578	0.024	0.549	0.624
Food-Away-from-Home (proportion)	416	0.613	0.013	0.594	0.643
Income ($ 1000 per capita)	416	21.326	1.453	18.786	23.881
Prod. Cons. (lbs. per capita, weekly)	416	1.956	0.345	1.194	3.277
Black Pop. (proportion)	416	0.126	0.070	0.028	0.227
Hispanic Pop. (proportion)	416	0.127	0.096	0.034	0.324
Asian Pop. (proportion)	416	0.034	0.029	0.015	0.109
Article Index (index)	416	4.827	3.290	1.000	14.000

The data were collected for the year 2000. All values are recorded in U.S. dollars.

Table 2. Canada Panel Data Summary.

Variable	N	Mean	Std. Dev.	Min.	Max.
Fresh Fruit Qty (lbs. per capita, weekly)	300	2.828	0.558	1.235	4.416
Fresh Veg. Qty (lbs. per capita, weekly)	300	2.745	0.478	1.631	5.098
Fresh Fruit Price ($/lb)	300	0.888	0.101	0.497	1.109
Fresh Vegetable Price ($/lb)	300	0.946	0.135	0.494	1.276
Meat Price (index)	300	115.749	14.094	16.190	128.167
Dairy Price (index)	300	111.650	13.124	12.090	118.299
Grain Price (index)	300	112.826	3.379	107.377	121.285
Processed Fruit (index)	300	105.184	5.370	95.115	116.224
Processed Vegetables (index)	300	103.032	3.545	93.887	114.369
Produce Expend. (cent per capita, wkly)	300	0.129	0.020	0.078	0.188
Household Income ($ 1000, annual)	300	47.305	5.084	41.289	54.291
Family Size (no.)	300	3.064	0.048	3.000	3.119
Educ. Expend. ($ per pupil, annual)	300	1.353	0.207	1.058	1.678
College Graduates (proportion)	300	0.126	0.016	0.105	0.149
Households with Children (proportion)	300	0.648	0.021	0.608	0.672
Women in Workforce (proportion)	300	59.864	3.229	56.060	65.600
Food-Away-from-Home (proportion)	300	0.278	0.030	0.230	0.325
Income ($ 1000 per capita)	300	16.427	1.112	14.747	17.943
Prod. Cons. (lbs. per capita, weekly)	300	5.573	0.839	3.211	8.330
Minority Pop. (proportion)	300	0.096	0.058	0.019	0.179
Article Index (index)	300	4.753	3.382	1.000	14.000

The data were collected for the year 2000. All values are recorded in Canadian dollars ($1 U.S. = $1.487 Canadian, 2000).

Table 3. MIMIC Model Estimates for U.S. and Canada.

	U.S.		Canada	
Equation / Variable	**Estimate[1]**	**t-ratio**	**Estimate**	**t-ratio**
Quality Structural Equation				
HH with Children	0.731*	1.892	4.291**	3.766
Women in Workforce	-6.743**	-2.318	0.010	1.557
Food Away from Home			9.678**	6.734
Quality Measurement Equation: Log Fruit Price				
Household Income	0.937**	68.708	-0.256**	-11.066
Household Income Squared	-0.011**	-79.004	0.003**	10.562
Family Size	1.162**	12.965	-0.402**	-2.989
Quality (latent)	1.000		0.280**	128.990
Quality Measurement Equation: Log Vegetable Price				
Household Income	0.440**	27.392	-0.558**	-7.523
Household Income Squared	-0.005**	-31.066	0.006**	7.451
Family Size	-0.071	-0.453	0.866**	2.215
Quality (latent)	3.623**	2.211	1.000	
Information Structural Equation				
Minority Population	-1.844**	-7.205	-1.627**	-4.030
Food-Away-from-Home	30.790**	37.240		
Women in Workforce			0.047**	8.857
Information Measurement Equation: Education Expenditures				
College Graduates	-21.941**	-16.798	-1.092	-1.086
Women in Workforce	0.485	0.686		
Income	0.509**	27.705		
Information (latent)	1.000		0.463**	9.502
Information Measurement Equation: Produce Consumption				
Black	-2.545**	-11.844		
Hispanic	2.985**	7.194		
Asian	-12.449**	-7.079		
Income	0.036	1.481	0.144**	6.978
Article Index	0.007*	1.868	0.017**	3.128
Information (latent)	0.201**	7.107	1.00	
Latent Variable Indices				
Quality (*mean and standard deviation*)	*9.852*	*0.023*	*6.069*	*0.230*
Information (*mean and std dev*)	*28.428*	*0.419*	*2.657*	*0.149*
H_0: Q_{US}/I_{US} - $Q_{Canada}/I_{Canada} = 0$	-1.944**	-226.825		

Two and one asterisks (** and *) indicate significance at the 5% and 10% levels, respectively.

Table 4. Per Capita Produce Demand in U.S. and Canada.

	U.S.		Canada	
Variable	**Fruits**[1]	**Vegetables**	**Fruits**	**Vegetables**
Log Fruit Price	-0.672**	-0.306**	-0.860**	-0.134**
	(-13.47)	(-5.83)	(-19.00)	(-3.02)
Log Vegetable Price	-0.115**	-0.886**	-0.148**	-0.869**
	(-2.44)	(-17.86)	(-3.58)	(-21.49)
Log Meat Price	4.643**	-5.276**	1.347**	-1.414**
	(6.21)	(-6.71)	(7.72)	(-8.30)
Log Dairy Price			-1.185**	1.238**
			(-7.80)	(8.34)
Log Grain Price	-10.785**	11.246**	-0.995**	0.982**
	(-9.07)	(8.99)	(-4.31)	(4.35)
Log Processed Fruit Price	2.268**	-2.636**	0.110	0.056
	(5.40)	(-5.97)	(0.81)	(0.42)
Log Processed Veg Price	1.464**	-1.556**	-0.707**	0.427**
	(5.30)	(-5.36)	(-3.28)	(2.03)
Log Produce Expend. per capita	1.090**	0.859**	1.132**	0.870**
	(41.07)	(30.77)	(33.66)	(26.48)
Log Quality Index	1.274	-1.625	1.224**	-1.225**
	(0.73)	(-0.88)	(6.11)	(-6.26)
Log Information Index	-0.133	0.376*	0.478**	-0.520**
	(-0.64)	(1.72)	(4.30)	(-4.80)
R^2	0.86	0.80	0.89	0.84
F-Value	268.82**	179.60**	235.60**	154.46**

The values in parentheses are t-values; two and one asterisks (** and *) indicate significance at the 5% and 10% levels, respectively.